IMPACT OF TRAFFIC INCIDENT ON A NETWORK WIDE LEVEL

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Abstract

Incident is apparently known as a source of traffic congestion. A number of ITS strategies have been implemented to minimize this problem however most of them were evaluated in microscopic level. This study utilizes a real world condition to model the incident in a freeway. Several scenarios were setup to recognize the impact of the incident to the system in the congested network wide. The scenarios were differed from one to the other by vary the number of lane closure and also the incident duration. Impact of multi incident is also examined in this study. The result of this study is expected to be a component account for assessing a proper ITS strategy to be implemented in an area
.

Key words: Incident, traffic congestion, ITS strategy, microscopic level, Impact

INTRODUCTION

Background

Incident appears frequently in a transportation network, especially at freeway. Traffic congestion in urban area mainly trigger by freeway incidents as stated in [1] [2]. The congestion induced by incident have caused higher cost for vehicle operation cost, time loss and higher emission that lead to worse air quality, and the direct bad effect of this congestion is it could generate the second or even furthermore incidents. Numerous Intelligent Transportation Systems (ITS) strategies have been addressed to reduce the congestion generated by incident. However typically these strategies were evaluated based on performance of the freeway corridor [3] [4] while so many times, instead of just influence transportation system performance in the corridor the congestion generated by incident affected whole transportation network.

This study tried to model incident happened particularly in freeway to see its impact in a network wide. Real world transportation network will be used in this research to reach the objective. At the end, it is hoped that this model can become a measure tool to assort the ITS approach that need to be applied in an area.

Study Objective

This study was conducted to answer the research questions as follow :

- *In the peak hour, will the incident duration and the severity of traffic incidents, measured by the number of closed lane in freeway, influence the transportation system performance at network wide level significantly, and if so, how*?
- *Will multi incident also influence the transportation system performance significantly*?

LITERATURE REVIEW

Congestion as a result of incident has been long known as an ordinary thing happened in freeway. Obviously, the congestion will result in delay to the traveler in the intervening road. To reduce the delay some researchers such as Stephanedes and Chassiakos [5] and Lin and Daganzo [6] were trying to conduct a study about incident detection in freeway. [5] in their study were evaluating the structure and performance of existing freeway incident detection and eventually proposed a new method in necessity to lower the likelihood of false incident decisions, while [6] were trying to proposed a freeway incident detection algorithm that claimed to be simpler and does not rely on complicated theories. They utilized the characteristic of delay – inducing incident to build a noncomplex incident detection algorithm. However, in spite of the effort that they did to have better incident detection system in freeway, both of them also stated the drawback of this system is the occurrences of false alarms. In fact, in their study they try to reduce and detect the false alarms to have more reliable information. Another problem about the incident detector is that it is considered as an impractical tool when it comes to the fact that the operator need to install the detector in every certain distance along the freeway and that special equipment to analyze the detector report also will be needed. At the end, the incident detection system using detector is categorized as high cost maintenance tools. The experience has thought that, the quickest and the most reliable incident detectors are the calls made by affected cellular-phone user on the road, and as stated in [6], that even the method they used for incident detection is not likely to change that.

The fact that incidents in freeways will significantly increase the vehicle travel time has led some researchers to find a better way in handling a freeway incident. However as the result of the previous studies described above, lesser study conducted to reduce delay by enhancing the automated detector system. Instead, incident management issues were raised to reduce the impact of incident that will, eventually, generate lesser delay to the road user. Jones et al [4] in their study about analysis of the frequency and duration of freeway accident in Seattle were utilizing statistical analysis of incident frequency and duration to have better management to diminish the effect of incident. The Poisson regression was utilized to model accident frequency while the model for incident duration was built base on hazard function. The founding showed that the characteristic of site and condition of incident are significantly related to the frequency and duration of accidents.

Duration of incident is one of the main factors that will determine the delay. Nam and Mannering [2] demonstrated that the incident times were significantly affected by a wide variety of factor such as detection/reporting, response and clearance times. Zhang and Khattak [7] studied about large event incident duration, found that longer incident durations were associated with longer service patrol response times, in addition they claimed that quick clearance can reduce the potential to have more incidents at the same time. Another study by Khattak et al [1] about the interdependency between incident duration and secondary incident, also supported this conclusion, stated that aggressive clearance will reduce the possibility of secondary incidents.

Giuliano [3] in his study about characteristic, frequency and duration of incident revealed that the variables related to incident duration are type of incident, time of day, truck involvement and lane closure. Golob et al [8], conclude that the duration of truck involved traffic accidents for homogeneous groups of accidents would be log-normally distributed, while Pal et al [9] reported that truck related accident spent 39.0 percent of all crashes clearance time.

The fact that delay caused by incidents are rare events as also stated in [6], has brought Hadi et al [10] to make an effort in modeling the capacity reduction as a result of incident using Microscopic simulation model. They concluded that the major calibration parameter for their model are, rubbernecking factor, lane changing behavior and cooperative lane changing behavior. In addition they suggested taking into account the consideration of advancement of ITS Technologies in a vehicle. Finally, from this literature review, it can be concluded that duration of incident and the number of lane closure have been considered as key factors for minimizing the delay caused by incident.

CONCEPTUAL STRUCTURE

Transport modeling at macroscopic, meso-scopic and microscopic levels

There are three levels of transportation modeling, Figure 1 demonstrates those levels in transportation modeling

Macroscopic level modeling

The characteristic of models at macro level :

1. Traffic assignment model based on static user equilibrium approaches
2. Planning models that applied on regional scale but have some incapability to model the level of detail required in congested area
3. Macro level modeling is the traffic modeling using the traffic flow
4. Do not require extensive data
5. Useful for route forecasting.

Mesoscopic level modeling

The characteristic of meso level models :

1. Traffic assignment model based on dynamic user equilibrium approaches
2. Operational model but can be applied on regional scale

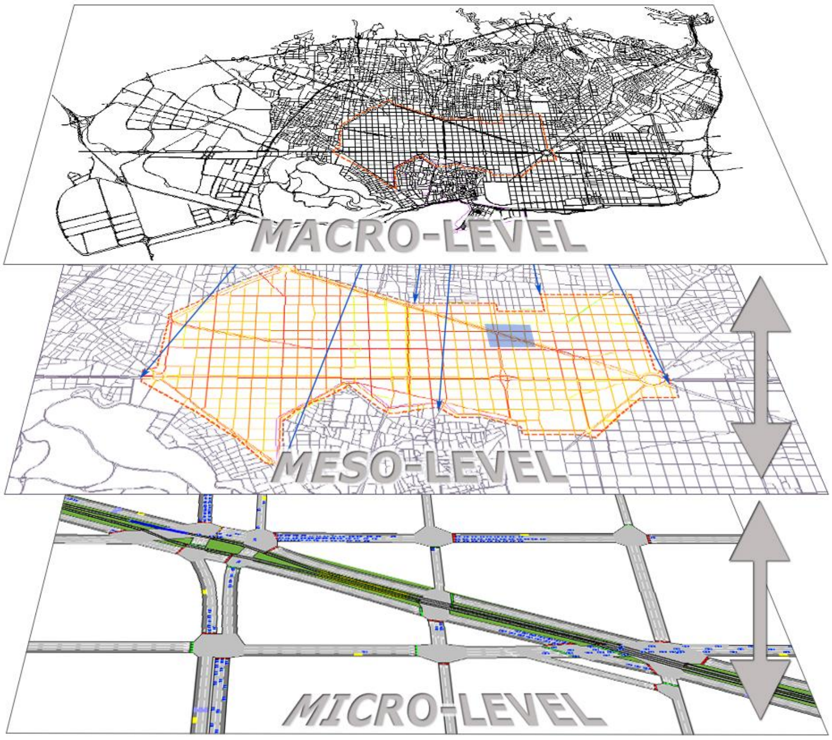

Figure 1. Different levels of modeling
(Source : Barcelo et al 2005, p.3[11])

3. Meso level modeling is the traffic modeling of vehicle platoon / packets. The output is the simulation of the packets. The size of the packets can be adjusted according to the necessity. When the packets size is set to minimum, the modeling become like micro simulation, on the other hand when the packet size is set to maximum, the modeling move toward the macro simulation
4. The data for this modeling is relatively the same with the data used in macroscopic level
5. Can be used for route forecasting.

Microscopic level modeling

The characteristic of micro level models :

1. Traffic assignment model based on dynamic user equilibrium approaches
2. Operational model that is suitable to be applied on a relatively small network but hardly to be applied in the regional level
3. Meso level modeling is the traffic modeling of individual vehicle. The output of this modeling is simulation of individual vehicle
4. Require extensive data
5. This modeling is not suitable to be used for route forecasting.

Transportation modeling using Cube Avenue

Cube Avenue is a component of Cube Voyager to perform dynamic traffic assignment. Cube Avenue applies the same PHASE structure with Cube Voyager Highway module but has additional command and keywords to handle the dynamic traffic assignment [12].

Cube Avenue is a transportation modeling at mesoscopic level. The model produces output at greater level of detail than macroscopic model, and at lesser level of detail than microscopic model, but enough to provide output for excellent traffic management strategies. Cube Avenue is transportation modeling that works using the same data as macroscopic modeling but offer relatively the same output quality for traffic management strategies as microscopic modeling. The comparison between macro level and meso level modeling is presented in table 1.

Nate Chanchareon,P.E. [13] from Citilabs gives the comparison between macro level using Cube Voyager Highway and meso level using Cube Avenue as shown in table 1. From table 1, it can be figured out that modeling at meso level is relatively more actual than at macro level. In modeling at meso level the vehicles can only be in

one place at the same time as happened in the real life and they do not appear along the route during the period as in modeling at macro level
Table 1 also shows that in modeling at meso level the volume cannot be more the road capacity. This is the reason for queuing and even blocking that are seen in the real life, become visible in modeling at meso level while they never happen in modeling at macro level. The consequences of queuing (or blocking) are taken into account for the travel time and travel cost which is factual in the real life, while in modeling at macro level the volume and cost are separately and independent.

The comparison between Micro-simulation and Meso-simulation (Cube Avenue) is shown in table 2 [13]. Table 2 shows that the modeling at micro level is more detailed than modeling at meso level, both input and output. On the input, the modeling at micro level needs more comprehensive data and network while the modeling at meso level needs relatively the same data and network as modeling at macro level. On the output, both of them can produce animations however in the modeling at micro level, the animation is in three dimension while at meso level it is only in two dimension. The consequences of modeling in more detailed in the modeling at micro level is that it need more intensive computation than modeling at meso level which can run in shorter times. Cube Avenue is a great tool to perform the following analysis [14]:

1. Identified the effect of traffic jam
2. Measure queuing and blocking in the network
3. Cut off the secondary impact between intersections
4. Assess the advantage of ITS (Intelligent Transportation System) project
5. Simulate different alternative infrastructure and operational
6. Emergency evacuation plans and strategies

Table 1The comparison between macro level and meso level

Macro level	Meso level
During period, a vehicle appears everywhere along its route	The packets of vehicle can exist only in one place at the same time and they are simulated
There is no change to the variables over the duration of the period in modeling	The flow rates are varied and there are ‘time segments’ as model period division
Capacity constraints not strictly enforced; V/C > 1	Capacity strictly enforced using “flow gates”
No link storage constraint	Storage strictly enforced
Link volumes and costs are separable and independent	Preceding link volume, cost was affected by the simulation of queues
Time = link traversal time + junction delay	Time = link traversal time +junction delay + queue time

Table 2The comparison between Micro-simulation and Meso-simulation (used by Cube Avenue)

Micro-simulation	Cube Avenue
Each vehicle is simulated individually	Vehicles can be grouped into homogenous packets
Complex flow interactions like weaving and merging	Uses aggregate speed/flow functional relationships
Explicit representation of facility lane geometry	Can be run using unaltered regional model networks
Produces three-dimensional animations of output results	Two-dimensional maps and animations possible in Cube
Computationally intensive	Much shorter run times

THE MODELING

The modeling will be conducted using the assistance of transportation software called Cube Avenue version 6.0.2. The main reason of using this packet of software is mainly because the data for the model i.e. Network and OD matrix were taken from static model established in Cube Voyager in the same version. Using Cube Avenue, which is derived from Cube Voyager, can avoid the complication of using the data and the network, since no import process is needed. Cube Avenue is Cube packet for modeling in mesoscopic level and performing dynamic assignment. It applied the capacity (and storage) restraint to build a path for the driver to find their routes and modified those routes in each iteration, however Cube Avenue simulates the movement of the vehicle and using it to evaluate the cost resulted from the route choice.

Input

The inputs for the model are the network, the origin destination matrix (OD Matrix) and the scenario that built inside the script in Cube Avenue Application. The network is Fredericksburg, Virginia, USA transportation network taken from the modeling in static model built in Cube Voyager. There are 3417 node, 923 zones and 7604 links in this network.

Similar to the network, the OD Matrix also was taken from AM Peak static assignment model. The duration for the AM Peak assignment is 2.6 hours. There are 10 OD matrix based on trip purpose and vehicle occupancy which are home based work (HBW) for single occupancy vehicle (SOV), HBW for heavy occupancy vehicle 2 person (HOV2) and HBW or heavy occupancy vehicle 3 person (HOV3), home based others (HBO) for SOV, HBO for HOV2 and HBO for HOV3, non-home based (NHB) for SOV, NHB for HOV2, NHB for HOV3 and the last matrix is for trucks. All of these matrices were placed in one input matrix file.

Output

The outputs for this modeling are output network and log file which is the file needed to conduct the simulation for the model. The output network contains output variable such as volume for the whole period, volume per time segment, congested speed, speed per time segment, queue per time segment and also blocking per time segment.

Beside the two output previously mentioned, there is also another output called “print file”. This file contain the summary of the result including vehicle miles travelled (VMT) and vehicle hours travelled (VHT). These two outputs are the main output for analysis in this study.

METHODS

Parameter and assignment

Although Cube Avenue performs Dynamic Traffic Assignment, it still uses Volume Delay Function (VDF) for the assignment as it is rooted from the Static Cube Voyager. In this model the Conical function was utilized as it is the function used in the static version model. The gap and relative gap for the model is set to 0.03. The reason to set the gap to that value is, this model has utilized packet splitting method that demand higher memory and simulation time.

According to Cube help [12], the Dynamic User Equilibrium employed by Cube Avenue was reached with two method which are packet splitting that used the traditional Method of Successive Average (MSA) and the other is a method offer by Cube which is called Packet Allocation. In the packet splitting, the new best path calculated for each iteration and packet’s volume is split across all available paths by creating new packets. Since there are new packets in every iteration, this method need higher memory usage and simulation time which eventually will lead to the run out of memory. On the other hand using Packet Allocation method, new best path is still calculated or each iteration and from this set of paths a path is selected using a uniform distribution for simulation. Since there are no new packet generated in each iteration, this method optimized the memory usage.

The decision to use packet splitting method was made after the unstable results produced by packet allocation method, where there is no certain trend both for VMT and VHT using the incident scenario.

The model period for this modeling is 456 minutes (7.6 hours) plus 30 minutes warm up period. The model period consist of 2.6 period of AM peak and 5 extra hours with zero demand to make sure that all the vehicles have reached their destination when the simulation is over, so that one can have a fair comparison of distance and travel time.

Single incident scenario

Sets of scenarios will be arranged to reach the goal of the study. Previous study conducted by Khattak, Wang et al [15] in the same state as the real world network for this study involved primary and secondary accident, shows that average lane closure is 30.1 minutes, maximum number of lane closed during the incident is 1, the mean of duration for all incidents for all of their all the data is 14.3 minutes while the average duration for primary incidents is nearly 37 minutes. Base on the result of this descriptive statistic, the scenarios for this study will be setup.

The first scenario is creating the model in the normal AM Peak Hour Period. The second scenario is by creating the model with incident that caused one lane is closed. For sensitivity analysis the duration of the incidents in this scenario was varied every 15 minutes, starting from 15 minutes to 60 minutes. As in Zhang and Khattak [7] incident duration is a crucial performance measure for addressing incident-induced congestion problems.

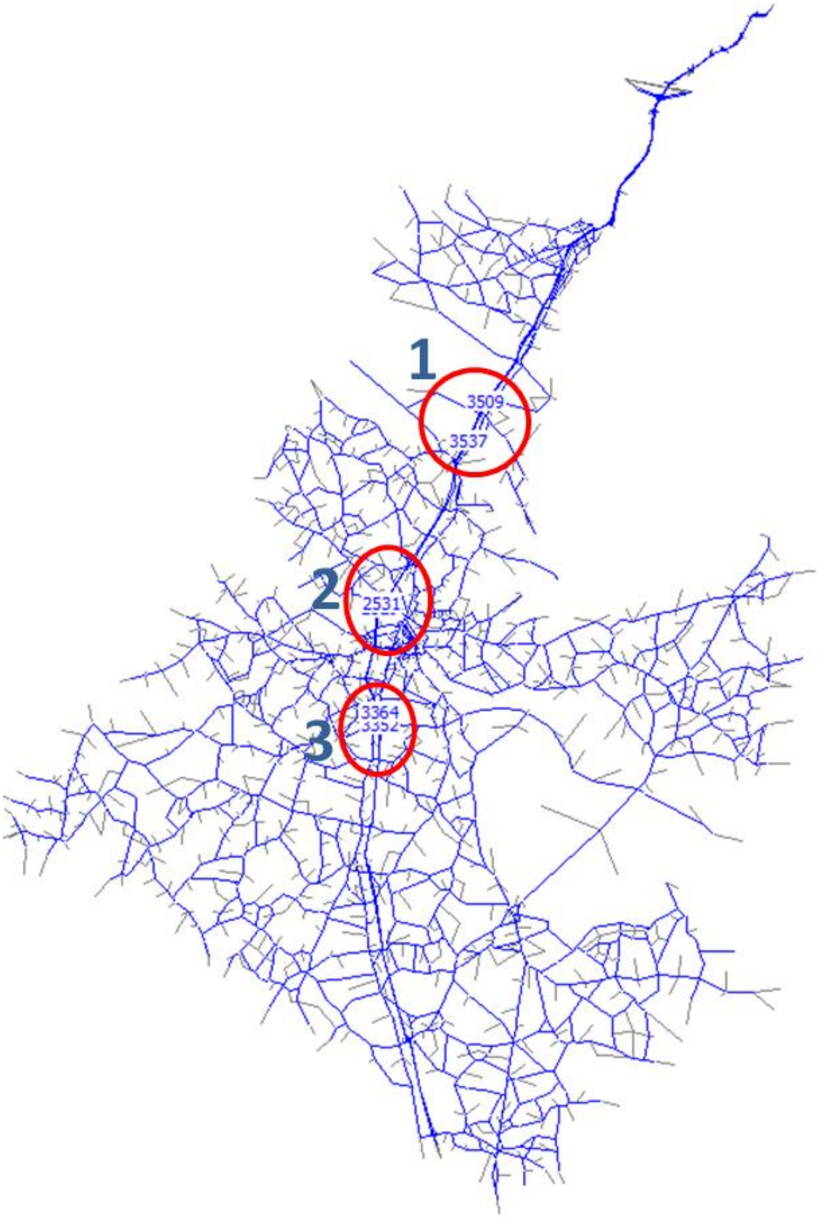

Figure 2 Incidents Location

The third and the fourth scenario were setup basically the same as the second scenario. The only difference is just in the number of lane closed, which are 2 and 3 lane closed for the third and the forth scenario, respectively. The reason for setting up the last two scenarios is, although the previous study shows that the maximum number of lane closed is 1, one need to put into account that the vehicle in the open lane did not move as fast as in normal condition, thus the capacity of the lanes are lesser than in typical condition. In addition, in a severe accident sometimes all the lanes in the freeway were closed

The objective of this set of scenario is to see how the effects of capacity changes as the result of incident in freeway influence the travel time for the whole system wide in a congested network. The measurement tool for this scenario is the total system average travel time which is the total average travel time from every origin zone to every destination zone.

Multi incident scenario

The next scenario is by creating multi incident. In this scenario the number of closed lane is two and the number of incident is from 1 to 3 incidents. The locations of second and third incidents were still in same freeway and all of the incidents were situated in the north bound. This setup was intended to threat the first and the third incident as the extension incident of the second incident. The locations of first, second and third incident was indicated in figure 2.

RESULTS

1. VMT and VHT of single incident scenario

Figure 3 has showed that as the incident duration increase, the VMT also getting higher. This is expected since at the time the incident takes place some vehicle will reroute. However this behavior is not significant for incident with 15 minutes duration. This could happen if the shortest path is not the shortest distance. Figure 1 also shows that as the number of lane closed increase the vehicle miles travelled also increase, which is expected because the number of vehicle reroute will getting higher as the number of lanes closed is increased. Although the shortest path is not the shortest distance where people will reroute, but at a certain point this path also will fully occupy, thus people will need to find other alternative that have longer distance than the original path.

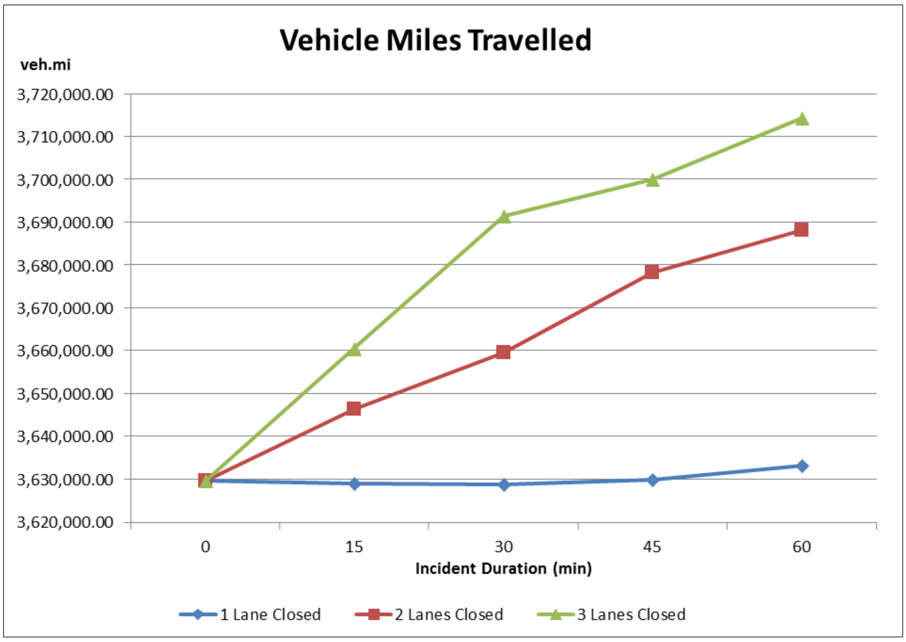

Figure 3. VMT for each incident scenarios

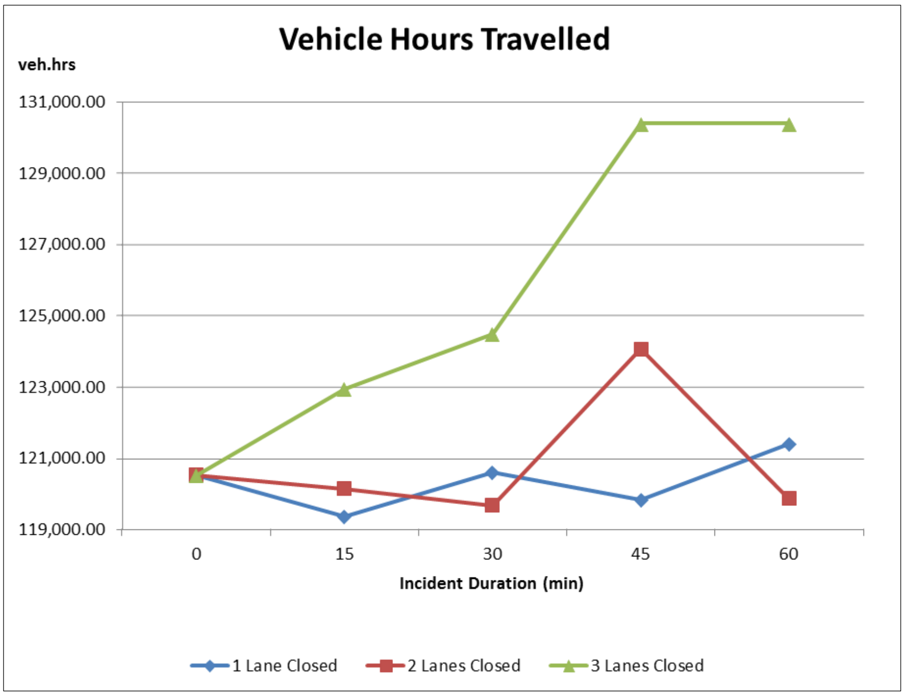

Figure 4. VHT for each incident scenarios

The vehicle hours travelled behaves differently with the vehicle miles travelled as shown in figure 4, except for the extreme case where all the lanes are closed. Some fluctuation of VMT values occurred for 1 and 2 lanes closed as the incident duration were increased.

Table 3. VMT Result Interpretation for addition of incident duration

□ VMT (Time)	Lane Closed		
	1	2	3
Δ1	3,718.56	21,121.08	35,321.88
Δ2	-211.48	13,259.90	30,924.68
Δ3	1,233.49	18,730.29	8,473.93
Δ4	3,224.85	9,875.17	14,374.95
Average	**1,991.35**	**15,746.61**	**22,273.86**

By taking the Δ (delta) values of VMT for every incident duration, table 3 shows that every addition of 15 minutes incidents duration for 1, 2 and 3 closure lanes will result in VMT addition on average 1991.35, 15746.61, and 22273.86 miles, respectively.

By taking the Δ (delta) values of VMT for every closure lane, table 4 points up that every addition of the number of closure lane for 15, 30, 45 and 60 minutes incident duration will also increase the VMT on average 15801.66, 31369.74, 34989.96 and 40565.01 miles, respectively.

Table 4. VMT Result Interpretation for addition of closure lane

Time	□ VMT (Lane Closed)		
	□ 1	□ 2	**Average**
15	17,402.52	14,200.80	**15,801.66**
30	30,873.90	31,865.58	**31,369.74**
45	48,370.70	21,609.22	**34,989.96**
60	55,021.02	26,109.00	**40,565.01**

2. VMT and VHT of multi incident scenario

Figure 5 demonstrated that the VMT are getting higher as the incident durations were increased as expected. However, although the differences are not significant some values of 2 incidents VMT are higher than 3 incidents VMT. The best explanation for this is again that the shortest path is not the shortest distance.

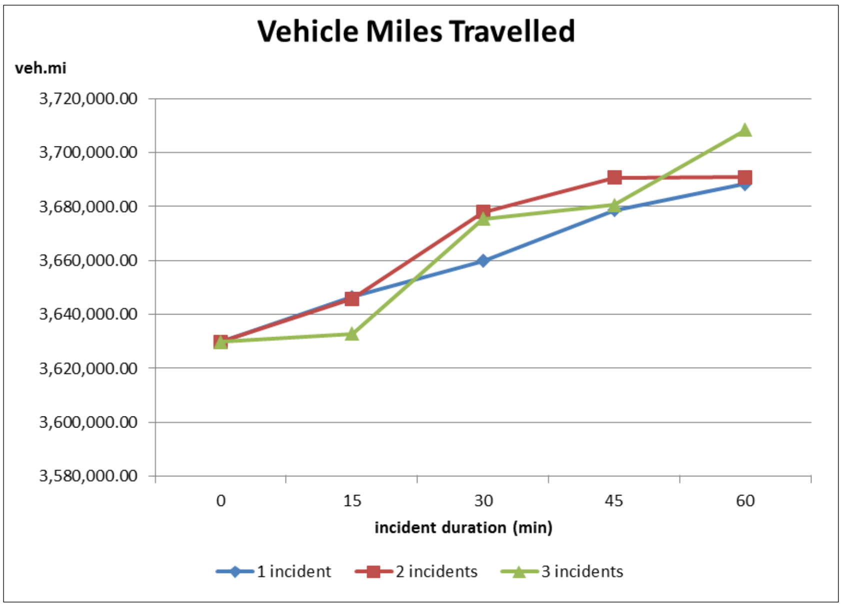

Figure 5. VMT for each incident scenarios (multi incidents)

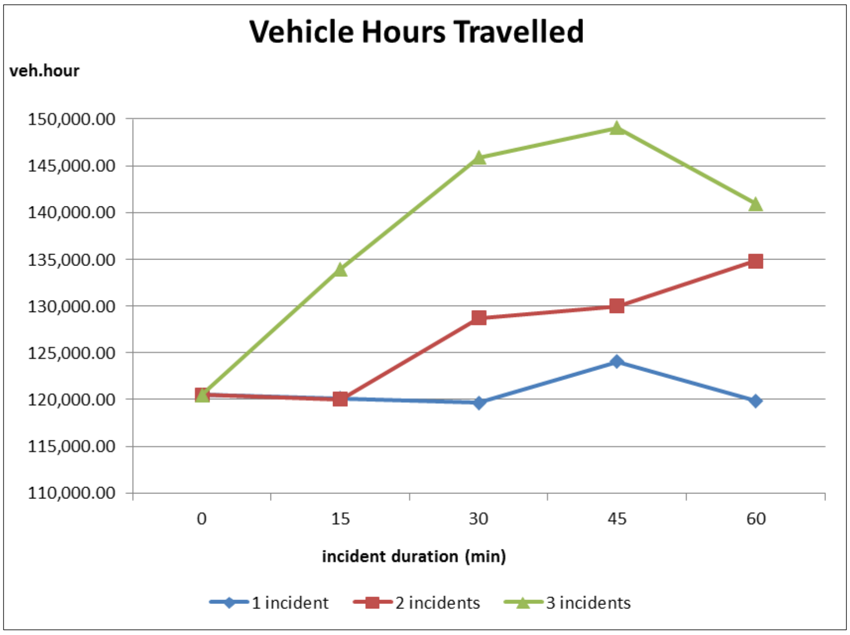

Figure 6. VHT for each incident scenarios (multi incidents)

Figure 6 shows similar behavior with the vehicle hours traveled for single incidents where there are some fluctuations for VHT values for 1, 2 and 3 lanes closed. This figure also shows that the addition of lane closed has end up to the higher VHT which is expected.

Table 5 shows the outcome of incident duration addition in multi incidents case, to VMT. As expected the VMT increase on average by 14643.95, 15249.15 and 19648.96 miles for one incident, two incidents, three incidents, respectively.

Table 5. VMT Result Interpretation for addition of incident duration (multi incidents)

Δ VMT (Time)	# incidents		
	1	2	3
Δ1	16,710.45	15,921.58	3,077.55
Δ2	13,259.90	32,206.10	42,438.73
Δ3	18,730.29	12,794.74	5,124.47
Δ4	9,875.17	74.19	27,955.09
Average	**14,643.95**	**15,249.15**	**19,648.96**

Table 6. VMT Result Interpretation for addition of closure lane

Time	Δ VMT (# of incidents)		
	Δ 1	Δ 2	**Average**
15	-788.87	-12,844.03	**-6,816.45**
30	18,157.33	-2,611.40	**7,772.96**
45	12,221.78	-10,281.67	**970.05**
60	2,420.80	17,599.23	**10,010.01**

Table 6 shows the consequences of the addition of number of lane closure. Unexpectedly the VMT for 15 minutes incident is decreasing by 6816.45 miles as the number of closure lane increase. While for 30, 45 and 60 minutes incident duration, the VMT increase as the number of closure lanes increase, which are on average 7772.96, 970.05 and 10010.01 miles respectively.

CONTRIBUTION TO INTELLIGENT TRANSPORTATION SYSTEMS

Modeling is a sophisticated way to replicate the real world situation and thus can produce reliable information. By knowing the effects of incident in several scenarios through modeling, one can employ this information to assess the feasibility of an ITS strategy since one among others basic principle to implement any traffic treatment or ITS strategy is the project's feasibility. This information can be used as a benefit component in assessing the feasibility study.

LIMITATIONS

There are some limitations noted in this project. In the real world situation when incidents happen, many people will not have the information about where and when the incident happens until they arrive in the incident site. Given that people may get information some of them will reroute and some of them will just wait until the incident clear. This situation cannot be represented in this modeling as Cube Avenue utilizes the Dynamic User Equilibrium which assumes perfect information for all drivers. The best type of assignment that can replicate this situation is stochastic assignment, however to the best of the author's knowledge, this type of assignment is not available in Cube Avenue.

Another limitation that should be notice in this study is the ideal gap and relative gap for the assignment convergence is 0.01, however in this assignment both of the cut off values were set to 0.03 for single incident and 0.04 for multiple incident (though for justification there are study that set the gap and relative gap to 0.1). The reason behind this is using the packet splitting method has caused higher computer memory usage which eventually lead to the run out of memory. By set those values to 0.03 has enabled the software to converge before the computer run out of memory.

CONCLUSION

By utilizing macroscopic model data, single incident and multi incident have been modeled and simulated. Transportation modeling is a sophisticated way to replicate the real life situation. This study has showed that transportation modeling at mesoscopic level that used data from transportation modeling at macroscopic level is able to demonstrate the impact of incident (single and multi-incident) to transportation system performance in a wide level.

In the study process, it is found that the packet allocation method in Cube Avenue can run much faster than the packet splitting that use Method of Successive Average (MSA) however the results are not stable. This fact has led the author to use the packet splitting method to analyze the incident impact.

This study also shows that in general the VMT increase as the duration and number of lane and also number of incident increase, while the VHT did not always represent this behavior except in the extreme situation such as all lane closed or in the 3 incidents situation.

Furthermore, the result showed that every addition of 15 minutes incident duration for 1, 2 and 3 lanes closed (1 incident) will result in the increase of vehicles miles travelled. Similar to that it is confirmed that every addition of lanes closed (1 incident) for every incident duration will also increase the vehicle miles travelled. Likewise, the increase in time and number of incidents will result in the increase of vehicle miles travelled except for increase in number of incidents for 15 minutes duration. The results of this study were expected to be used in assessing an appropriate

ITS strategy and even contribute to traffic safety policy.

FUTURE STUDY

This study utilize dynamic user equilibrium assignment that assume perfect information for all drivers, it can be justified as this study was utilized data of a real world congested situation. However for future study, one may need to apply the stochastic user equilibrium to better represent the real world condition especially in non-congested network.

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